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# **Over- and underestimation of motor ability after a stroke: Implications for anosognosia**

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## **Abstract**

We administered a discrepancy-based measure of anosognosia for hemiplegia (AHP) to a group of 42 right-brain-damaged (RBD) and left-brain-damaged (LBD) stroke patients with varying levels of functional motor ability. In addition to the expected (anosognosic) pattern of overestimation of motor function in some RBD patients, we found an equal and opposite underestimation in some others, both RBD and LBD. We also found that around a quarter of self-estimation error could be predicted directly from actual ability, such that patients with poorer motor function tended to overestimate, and vice versa. This pattern suggests that some misestimation is attributable simply to statistical regression. However, even after adjusting for this regression effect, levels of overestimation were significantly greater in RBD patients, while LBD patients were more likely to underestimate their motor ability.

Keywords: Anosognosia; Hemiplegia; Stroke; Metacognition; Insight; Self-estimation

# 1. Introduction

Anosognosia for Hemiplegia (AHP) is a term coined by Joseph Babinski (1914) (translated in Langer and Levine, 2014) for a condition in which people suffering from brain damage fail to recognise or acknowledge their motor weakness or paralysis (Mograbi and Morris, 2018). AHP is unusual in being a meta-deficit that exists only in relation to a primary impairment: one cannot be unaware of a symptom that one does not have (Gasquoin, 2016). Studies of AHP thus necessarily tend to recruit patients with some degree of hemiparesis, typically moderate to severe (Hartman-Maeir et al., 2001; Marcel et al., 2004; Moro et al., 2011). However, there are potential statistical confounds in selecting only the most functionally impaired patients to measure self-estimation. These issues have been addressed in the literature on metacognition in non-clinical populations but, to our knowledge, have not yet been considered in relation to AHP.

Kruger and Dunning (1999) suggest that a “psychological analogue to anosognosia” (p. 1130) can be observed in people who are unskilled at a task and yet greatly overestimate their ability. This phenomenon, the ‘Dunning-Kruger’ effect, has been demonstrated in several different cognitive tasks, where overestimation among the least skilled is typically observed alongside a less pronounced underestimation among the most skilled (Dunning et al., 2003; Ehrlinger et al., 2008; Haun et al., 2000; Hodges et al., 2001). To account for this, Kruger and Dunning (1999) proposed a specific lack of insight among the worst performers, hypothesising that the ability to recognise one’s own shortcomings on a task depends upon the same set of competencies required to perform the task: lacking these skills, the poorest performers suffer the ‘double-curse’ of being unable both to do the task well and to recognise this inability (Ehrlinger et al., 2008; Kruger and Dunning, 1999). Conversely, the most skilled individuals tend to underestimate their own performance.

However, as several commentators have pointed out, a more prosaic explanation of these patterns is possible through regressive biases in self-estimation (Burson et al., 2006; Krueger and Mueller, 2002; McIntosh et al., 2018). Assuming only that people have imperfect knowledge of their actual performance, their estimations will tend to err towards an average level, so if we select a sub-group of participants by extreme

actual performance (whether low or high), it is practically certain that their self-estimates will be less extreme, thus ensuring apparent overestimation among the worst performers and underestimation among the best performers. The real or artefactual nature of the Dunning-Kruger effect is still a matter of debate, but in principle the selection of participants by extremely poor actual performance could inflate observed overestimation via this simple statistical bias.

Is it possible that a similar mechanism could contribute to the apparent unawareness of movement problems among hemiplegic patients? This explanation seems inadequate to account for outright denial of deficit, as described by Babinski (1914), where a completely hemiparetic patient insists that they can move their limb normally. However, it may be applicable to more recently developed, continuous measures of AHP, which quantify the degree of misestimation through the discrepancy between self-estimated ability and actual ability, either observed directly or inferred from caregiver ratings. For example, the Visual-Analogue Test assessing Anosognosia for Motor Impairment (VATAm: Della Sala et al., 2009) is one such measure. This verbal and pictorial scale calculates the discrepancy between self- and caregiver-ratings on 12 questions assessing awareness of the ability to carry out bimanual or bipedal actions.

Discrepancy scales like the VATAm are focused on the identification of abnormal overestimation. While bidirectional cut-offs could be used to additionally detect underestimation, this is typically not the object of study and, where underestimation is observed, it may be suggested as a symptom of depression (Della Sala et al., 2009). In general, non-anosognosic patients are anticipated to have clear insight into their movement ability, and therefore to rate themselves equivalently to their caregivers. However, presuming that the patients have some degree of uncertainty over their true level of ability and/or the caregiver estimates are themselves subject to chance variations, self-estimates are likely to be regressive with respect to the caregiver ratings. In this case, a Dunning-Kruger type pattern would emerge, manifesting as extreme overestimation in the most functionally impaired, and underestimation in the most physically mobile. The main aim of this study was to administer a discrepancy measure of AHP to a group of stroke patients across a range of functional motor ability to investigate whether misestimation would be observed in both directions (i.e. under- as well as overestimation), and assess the degree to which this is predicted by

the patients' actual levels of ability. Given the commonly observed association of AHP with right hemisphere lesions, we also aimed to compare misestimation tendencies between right-brain-damaged (RBD) and left-brain-damaged (LBD) patients.

## 2. Material and methods

### 2.1. Participants

Patient recruitment took place on the acute stroke ward at the Royal Infirmary of Edinburgh, across a continuous 21 month period. Inclusion criteria were the presence of a stroke, determined by CT/MRI scan and neurological examination, and the capacity to consent to medical treatment, as recorded in patient notes. Exclusion criteria were: inability to communicate sufficiently in English, either through not speaking English as a first language or through severe aphasia; diagnosis of a concomitant neurological condition, dementia or major psychiatric disorder; a history of substance abuse or serious head injury causing loss of consciousness. Informed consent was obtained from all patients prior to participation. Ethical approval for the research was obtained from the South East Scotland NHS Ethics Committee.

One hundred and thirty seven patients were approached in total, of whom 55 (40%) agreed to participate. Two were excluded after testing because it was discovered that they did not in fact meet the inclusion criteria, leaving a total sample of 53 patients with complete or partial data. Eleven of these patients were subsequently excluded from the analyses; lesion and clinical information was unavailable for five patients, three had evidence of bilateral lesions on their neuroimaging scans and three were missing data on the critical measure of movement self-estimation. The final sample consisted of 42 patients, 12 with lesions to the left hemisphere (LBD group) and 30 with lesions to the right hemisphere (RBD group). Where the data were incomplete for any measure, pairwise deletion was used in the analyses (Ns are shown in Tables 1 and 2).

Basic demographic and clinical information is provided in Table 1. The LBD and RBD groups did not differ significantly in terms of their gender distribution [ $\chi^2(41) = 0$ ,  $p = 1$ ], their age [ $t(18.98) = -.66$ ,  $p = .52$ ], years of education [ $t(17.69) = .58$ ,  $p = .57$ ], days since stroke [ $t(24.64) = -.105$ ,  $p = .31$ ], upper limb motor power on the affected side [ $t(24.96) = 1.19$ ,  $p = .24$ ], lower limb motor power on the affected side [ $t(20.85) = .39$ ,  $p = .70$ ], or ability to carry out basic activities of daily living, as measured by the Barthel Index (Mahoney & Barthel, 1965) [ $t(18.47) = .63$ ,  $p = .53$ ].

The groups did not differ significantly in terms of the frequency of visual field loss [ $p = .43$ , two-tailed Fisher's exact test]. However, there was a higher rate of contralesional somatosensory loss in the RBD group than the LBD group [ $p = .01$ , two-tailed Fisher's exact test].

<b>Group</b>	<b>LBD</b>	<b>RBD</b>	<b>Total</b>
N	12	30	<b>42</b>
Gender	F = 7, M = 5	F = 16, M = 14	<b>F = 23, M = 19</b>
Age, M (SD)	70.25 (12.74)	73.07 (11.79)	<b>72.26 (11.98)</b>
Years of education, M (SD)	13.00 (3.57)	12.32 (2.93), N = 28	<b>12.53 (3.1), N = 40</b>
Days since stroke, M (SD)	9.73 (7.75), N = 11	12.96 (9.92), N = 24	<b>11.94 (9.31), N = 35</b>
Power (0-5)			
Right upper limb, M (SD)	3.63 (1.50), N = 11	5.00 (0), N = 21	<b>4.53 (1.08), N = 32</b>
Right lower limb, M (SD)	3.45 (1.75), N = 11	4.95 (0.22), N = 21	<b>4.44 (1.24), N = 32</b>
Left upper limb, M (SD)	5.00 (0), N = 11	2.90 (1.89), N = 21	<b>3.62 (1.83), N = 32</b>
Left lower limb, M (SD)	5.00 (0), N = 11	3.20 (1.77), N = 20	<b>3.84 (1.66), N = 31</b>
Somatosensory loss, N/valid	2/11 (18%)	15 /22 (68%)	<b>17/33 (52%)</b>
Visual field deficit N/valid	2/11(18%)	7/20 (35%)	<b>9/31 (29%)</b>
Barthel Index (0 - 20), M (SD)	12.73 (6.29), N = 11	11.31 (6.44), N = 29	<b>11.70 (6.35), N = 40</b>

Table 1. Demographic and clinical data for the final sample of 42 participants.

Number of participants is shown for any measure where data were available for fewer than the total number.

## 2.2. Measures

### 2.2.1. The Visual-Analogue test assessing Anosognosia for Motor Impairment (VATAm)



The VATAm (Della Sala et al., 2009) contains 12 test items representing bimanual or bipedal actions, for example ‘tying a knot’ or ‘walking upstairs’, each with both a verbal description and visual depiction. Respondents are required to mark on a horizontal scale, from 0 ‘No Problem’ to 3 ‘Problem’, the difficulty they would have in trying to perform each action.

The scale was completed by both the patients and a professional caregiver, usually an Occupational Therapist. The caregiver scores were taken as the measure of functional motor ability, which was then compared with self-rated scores, and the discrepancy was calculated as the raw self-estimation error. These scores had a potential range of -36 to +36, with zero representing total agreement, negative scores underestimation and positive scores overestimation.

### *2.2.2 Cognitive ability: the Birmingham Cognitive Screen (BCoS)*

The BCoS (Humphreys et al., 2012) is a broad-but-shallow battery of neuropsychological tests for the assessment of cognitive function following stroke. The battery contains 22 subtests, consisting of 32 different elements (some tasks, for example, have an accuracy and a time component) that assess cognition in five different domains: attention and executive function, language, memory, number skills, and praxis. Tasks not directly assessing language or spatial ability are designed to be suitable for administration to patients with aphasia or neglect, respectively (Bickerton et al., 2015).

For the purposes of this study, composite scores were derived to summarise cognitive status in the domains of language, memory and attention. Only subtests with  $\geq 35$  observations were included in these composites. Scores on the picture naming, sentence construction, reading sentences and reading nonwords subtests were converted to percentages and then averaged to provide language domain scores. Similarly, for the memory domain, scores on the orientation, personal information, story recall (immediate) and story recognition (immediate) subtests were converted to percentages and then averaged. As the majority of subtests in the domain of attention and executive function had fewer than 35 observations, we derived a score specifically for spatial attention using the apple cancellation test; we first calculated

the number of targets correctly cancelled (out of 50), multiplied by 2, and then subtracted the number of distractors incorrectly cancelled (out of 100), yielding a possible score of between -100 and +100.

### *2.2.3 Mood assessment: Visual-Analogue Mood Scale (VAMS)*

Mood was assessed using the Visual-Analogue Mood Scale (Stern et al., 1997), on which the patients rated, from 0 to 100, the extent to which they were feeling eight different moods: afraid, confused, sad, angry, energetic, tired, happy and tense. Each one was presented both in written format and by a cartoon icon (emoticon), and participants were instructed to mark on a 100mm vertical scale the point which best described how much of that mood they were feeling. Scores for each of the eight moods were calculated by measuring the distance of the mark from the top of the line in mm, and could range from zero to 100. The scores for the six negative items (afraid, confused, sad, angry, tired, tense) were flipped and all eight items were averaged to form a single composite measure of mood.

### *2.2.4 Other measures*

In addition to the main measures outlined above, exploratory analyses were also conducted to assess self-estimation of cognitive performance on two of the BCoS subtests measuring memory (immediate story recall) and spatial attention (apple cancellation). These exploratory analyses did not yield any significant findings, and were hampered by low participant numbers (see data in supplementary materials).

## **2.3. Procedure**

Testing took place at the bedside, behind a screening curtain, or in a private room if the patient preferred. The tasks were always given in the following order: VATAm;

VAMS; digit span; BCoS (subtests presented in set order). Tasks were completed in one or two sessions.

### 3. Results

Table 2 shows scores in the BCoS domains of language, memory and spatial attention, and VAMS mood ratings, separately for LBD and RBD patients, and for both groups combined.

	Overall (N = 42)	LBD (N = 12)	RBD (N = 30)
BCoS domain scores:			
Language	88.05 (11.74), N = 40	85.78 (10.97)	89.02 (12.12), N = 28
Memory	85.31 (7.23), N = 39	85.17 (6.60)	85.37 (7.62), N = 27
Spatial Attention	75.70 (28.42), N = 37	91.27 (11.84), N = 11	69.12 (30.91), N = 26
VAMS mood ratings	61.54 (19.34), N = 38	65.22 (17.67)	59.85 (20.17), N = 26

Table 2. Scores on the cognitive and mood measures

There were no significant differences between LBD and RBD patients in their VAMS mood ratings (LBD median = 70.25, RBD median = 60.25) [ $W = 177$ ,  $p = 0.53$ ], or in the cognitive domains of language (LBD median = 88.39, RBD median = 92.11) [ $W = 118.5$ ,  $p = .15$ ] or memory (LBD median = 86.25, RBD median = 88.33) [ $W = 156.5$ ,  $p = .88$ ]. Unsurprisingly, RBD patients had significantly lower scores in the spatial attention domain than LBD patients (LBD median = 95, RBD median = 84) [ $W = 224.5$ ,  $p = .007$ ] (Figure 1).

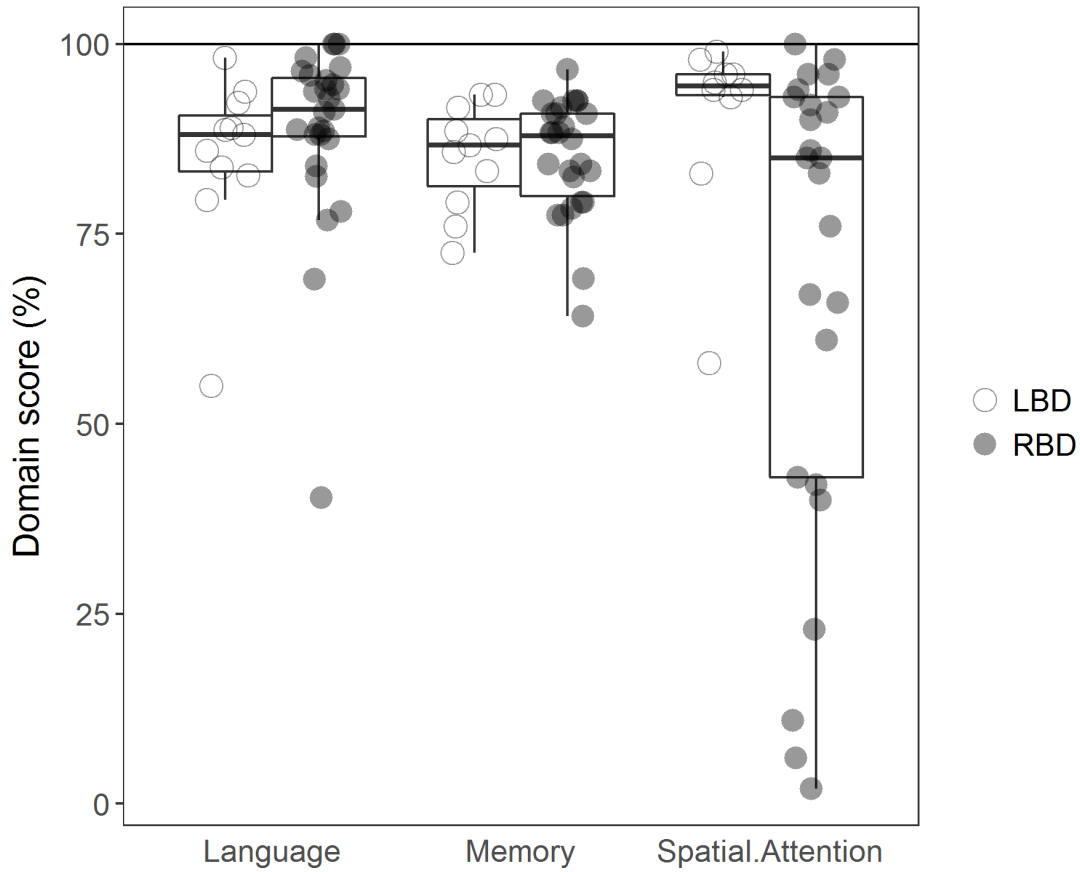


Figure 1. Cognitive scores by domain and lesion side

### 3.1 Self-estimation of movement skill

VATAm caregiver scores were highly correlated with Barthel Index scores [ $\rho(38) = -.89, p < .001$ ], suggesting that either measure provided a reliable representation of functional motor ability. The Barthel Index was employed in subsequent analyses as the measure of actual motor ability.

The distribution of VATAm raw self-estimation errors showed substantial variation in both directions, and instances of extreme underestimation were observed in addition to the expected overestimation, indicating that different patients underestimated and overestimated their movement ability to somewhat equivalent degrees. However, the self-estimation error was significantly predicted by functional motor ability, [ $F(1, 38) = 12.14, R^2 = .24, \beta = -.75, t(38) = -3.48, p = .001$ ], suggesting that around a quarter

of the variation in misestimation measured by this discrepancy-based scale is attributable to actual ability, and therefore potentially to a regressive bias in the measurement of self-estimation (Figure 2).

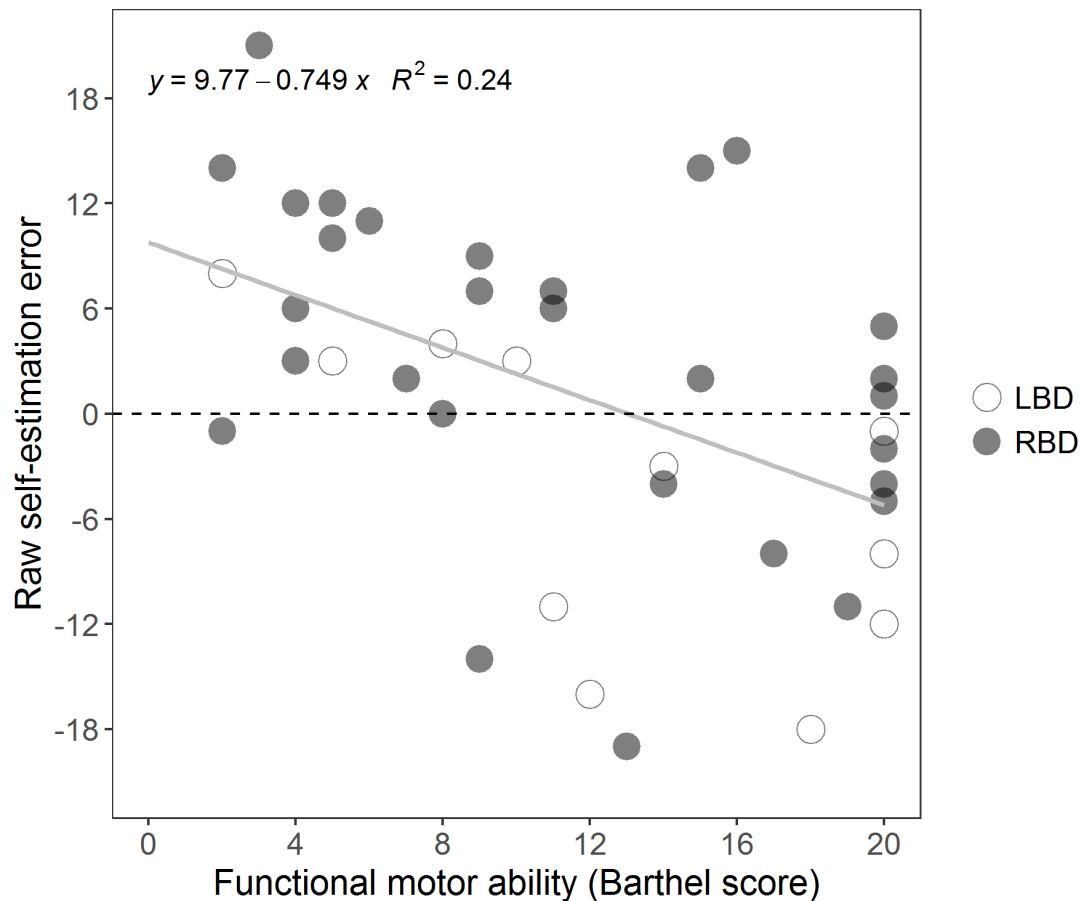


Figure 2. Raw self-estimation error plotted against functional motor ability. The horizontal dashed line (slope = 0) shows the relationship predicted if self-estimation were perfect, and the line of best fit (slope -.75) is shown in grey.

To remove the proportion of estimation error explained by this regressive bias, the residuals from the above linear regression model were saved as a measure of adjusted self-estimation error. This adjusted value is the difference between the observed self-estimation error and the predicted self-estimation error at the participant's level of functional motor ability, i.e. self-estimation error after the component attributable to the regressive bias has been removed.

Raw and adjusted self-estimation errors for LBD and RBD patients are shown in Figure 3. The dotted lines at +6 and -6 indicate standard cut-offs between normal awareness and mild over-/underestimation, based on the mean discrepancy between two caregivers rating the same patient, plus or minus two standard deviations (Della Sala et al., 2009).

Looking at Figure 3, it is apparent that individually underestimation can be as extreme as overestimation. However the patterns differed according to side of lesion. While some RBD patients did underestimate ( $N = 10$ ), many more overestimated ( $N = 19$ ). Conversely, only three LBD patients mildly overestimated their functional motor ability, while eight underestimated. Once the adjustment for the regressive bias had been made, the only instances of significant misestimation amongst LBD patients were instances of underestimation.

At a group level, a Wilcoxon rank sum test on raw self-estimation error scores demonstrated that RBD patients (median = 3) were significantly more likely to overestimate their ability than LBD patients (median = -3) [ $W = 89.5$ ,  $p = .04$ ]. This pattern was observed even when actual motor status had been accounted for in the adjusted scores: (RBD patients median = 3.98, LBD patients median = -2.78) [ $W = 82$ ,  $p = .02$ ].

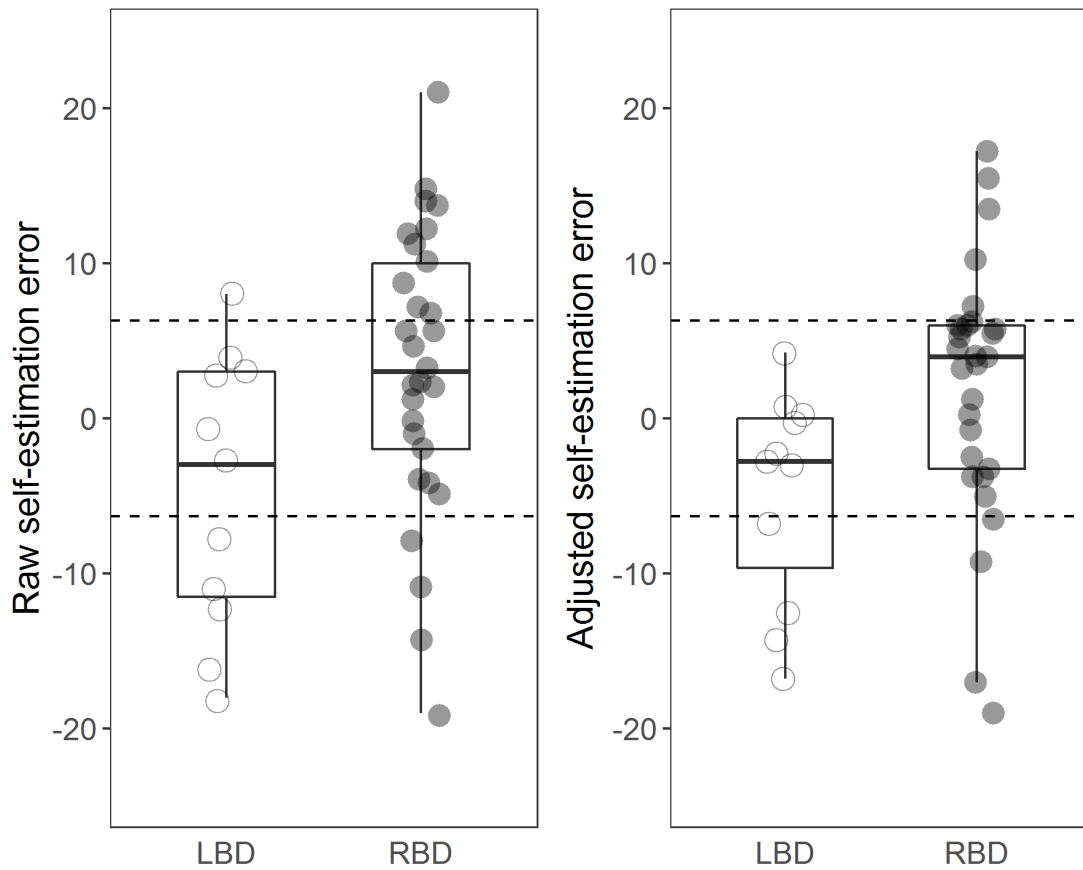


Figure 3. Raw and adjusted self-estimation errors by lesion side. Dotted lines indicate cut-offs for mild over-/underestimation (Della Sala *et al.*, 2009)

### 3.2 Relation to mood and cognition

Exploratory analyses were run to assess whether there was any relationship between adjusted self-estimation errors and VAMS mood composite ratings, and scores in the cognitive domains of language, memory and spatial attention. Spearman correlations showed a significant association between mood and adjusted self-estimation errors: participants who reported lower moods tended to underestimate their movement ability [ $\rho(34) = .37$ ,  $p = .03$ ]. Spearman correlations revealed no significant association between adjusted self-estimation errors and language ability [ $\rho(36) = .06$ ,  $p = .73$ ], but there were possible trends towards an association with memory [ $\rho(35) = -.29$ ,  $p = [0.09]$  and spatial attention [ $\rho(33) = -.32$ ,  $p = [0.06]$ ].



## 4. Discussion

We administered an established continuous scale of movement self-estimation, the VATAm, to a group of stroke patients with varying motor status. Levels of underestimation were similar in degree and magnitude to levels of overestimation. From this study, there is no evidence that stroke patients with good movement ability estimate themselves any more accurately than those with motor impairments, though they may tend to misestimate in the opposite direction. Regressive estimates may have inflated discrepancies between self and other ratings at the extreme ends of the functional ability scale, suggesting that the same statistical mechanism that has been proposed to account for the Dunning-Kruger effect in healthy individuals (Burson et al., 2006; Krueger and Mueller, 2002) could also be a confound in patient studies. It is therefore important that researchers take steps to avoid conflating regressive estimates with genuine AHP, for example by matching AHP and non-AHP groups for their level of functional motor ability, or using different measures to calculate discrepancy scores and determine actual motor ability. Assessing self-estimation across multiple domains could provide an indication of whether over- or underestimation of motor ability generalises to other functions.

It should be noted that our participant group did not contain any patients with raw self-estimation errors exceeding the +24 cut-off for severe anosognosia on the VATAm (Della Sala et al., 2009), so it may be that no clear qualitative cases of florid anosognosia were included. It is not possible to say, on present evidence, whether comparable magnitudes of under- and overestimation would be observed at more extreme ends of the scale, or whether extreme misestimation would be more specific to overestimation (i.e. AHP). However, there were a couple of features within our data that suggested that factors beyond a regressive bias contributed to over- and underestimation. First, overestimation was the dominant tendency amongst RBD patients, although instances of underestimation were also observed in this group. By contrast, the only significant instances of misestimation in LBD patients were in the direction of underestimation. The small LBD group size makes this finding necessarily speculative, however it would be an interesting avenue for future research to determine whether self-estimation in LBD patients is generally characterised by

underestimation, as opposed to the known association between RBD and overestimation.

A second feature of note was the observed association between mood and self-estimation, which could reflect a tendency among people experiencing lower moods to underestimate their physical ability, and/or that those who overestimate have a degree of anosodiaphoria or unconcern for their motor impairments (Langer and Levine, 2014). Previous research has highlighted the association between unawareness and unconcern, with the latter sometimes considered to be a milder version of the former (Heilman et al., 1998; Vocat et al., 2010). A possible role of emotional states in engendering or maintaining unawareness has also been demonstrated; for example, inducing negative emotions in AHP patients may temporarily improve motor awareness (Besharati et al., 2014). Lesion studies have shown that damage to brain regions involved in emotional processing, such as the insular cortex, is also implicated in disorders of bodily awareness (D'Imperio et al., 2017; Moro et al., 2016).

There are some limitations to this study that should be highlighted. It is surprising that no differences were observed between LBD and RBD patients in scores in the language domain, which may partly reflect the lower numbers of LBD patients, as well as a bias towards inclusion of those with intact language skills, either through self-selection or the inclusion criterion of being able to communicate sufficiently in English. The relatively small sample size and non-normality of data make the analyses of self-estimation and cognitive scores necessarily exploratory. Furthermore, there is inevitable variability in data collected in the acute stages after a stroke, when cognitive, emotional and awareness symptoms fluctuate considerably, which may have been exacerbated by the difference in size between the LBD and RBD groups. We have tried to mitigate these issues through the use of non-parametric analyses. Future research could usefully investigate whether studies with a larger sample size would reveal an association between over- /underestimation and impairments of spatial attention (which showed a possible trend towards an association with overestimation in our data) or scores in other cognitive domains, such as executive function.

We began this paper with the observation that AHP is a ‘meta’ deficit that can only be observed in relation to a primary impairment. Our findings suggest that the picture is more nuanced than this. On the one hand, the observation of under- as well as over-estimation suggests that even people with little or no physical impairment after a stroke can have an unrealistic impression of their post-stroke function, and that this can occur in both LBD and RBD patients. However, we also found that, even after adjusting for actual motor ability, overestimation was greater in RBD patients, consistent with a right hemisphere association for this particular pattern of misestimation, while underestimation was observed more frequently after left hemisphere damage.

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